Functional magnetic resonance imaging (fMRI) is a powerful technique because of the high spatial resolution and the noninvasiveness. The applications of the fMRI to the auditory pathway remain a challenge due to the intense acoustic scanner noise of approximately 110 dB SPL. The auditory system consists of multiple processing centers, distributed across the medulla, pons, midbrain, thalamus, and temporal cortex. This thesis treats two main topics (1) possible improvements of the fMRI acquisition of the auditory brainstem nuclei and (2) an application of fMRI to the central auditory system in a study of the perceptual illusion of the McGurk effect. For both experiments, images were collected using a 3T Philips Intera scanner equipped with an 8-channel SENSE head coil.

The first topic is on the research of the available technical options for the fMRI brainstem acquisition. A review of the literature on the auditory brainstem fMRI experiments is reported in chapter 2, with a preponderant outline on the methodology used in scanning, which involves experimental design, type of stimuli, and analysis of the effect of motion of the brainstem. Pilot studies were performed to establish the optimal type and the intensity of stimuli, the fMRI paradigm, the scanning parameters (repetition time and number of slices), and the reflection of the response in the fMRI data. This culminated in the selection of the experiment for the auditory brainstem study reported in chapters 3 and 4. These chapters describe an experiment which was chosen to investigate if there are differences between three slice orientations through the brainstem. The orientations of the slices were chosen in relation with the expected motion of the brainstem,

1. in the rostro-caudal direction: orthogonal to the brainstem and to the main direction of the brainstem motion – called orthogonal,
2. parallel with the brainstem and perpendicular to the sagittal plane – named parallel, and
3. at 45 degrees to the brainstem and to the parallel plane define above (2) – called 45 degrees.

Even though there are no clear data in the literature that unequivocally prove that the upper brainstem (inferior colliculi) moves differently than the lower brainstem (cochlear nuclei and superior olivary complex), at least regarding the magnitudes, our expectations were that we would find differences in the slice orientation effects in the responses in the lower and upper brainstem. Motion of the brainstem arises from several correlated factors, such as vasculature (arteries and veins attached to the brainstem which cause a movement with each arterial pulsation), cerebrospinal fluid movement, and tissue deformation. In our fMRI data analysis we calculated the following parameters, number of activated voxels, intensity, standard deviation, normalized standard deviation, effects size, and mean t-values.

Our results indicate that for the midbrain and auditory cortex the motion due to heart beat is less reflected in data acquired in the 45 degrees orientation
plane, as revealed in the SD and NSD of the residuals. For the medulla (cochlear nuclei) and pons (superior olivary complex) we did not find any significant differences.

It is important to understand that the “noise” in the analysis refers to any parameter that is not included in the preselected parameters of interest. It still remain debatable how much the brainstem moves and how this affects the BOLD signal, even though almost every publication mentions that the motion of the brainstem with each heart beat constitutes a problem in imaging this structure. There are no well defined data concerning the size and duration of the motion of the brainstem. Values for the amplitude and velocity of the motion vary in the literature with the MRI technique used, and hence, further studies apparently are needed on this issue.

The second topic is the study of an auditory illusion (MGurk effect) produced by the view of lip movements that are realized by the pronunciation of sounds that differ from the presented ones. This experiment involves multisensory integration, essential for achieving complex behaviors. Speech, for example can be perceived by listening to the speech sound, and also by watching the articulating movements of the mouth. The bimodal integration of audio and visual information in perceiving speech has been demonstrated by the McGurk effect. Chapter 5 describes the psychophysical and fMRI experiments on the audio-visual integration in speech perception that is observed using the McGurk effect. On the basis that the strength of the McGurk effect reflects the strength of AV integration, we expect to find a correlation in the brain activation and AV synchronicity. Before the fMRI measurements, the psychophysical experiments were performed to select the stimuli and the subjects sensitive to the McGurk effect. The strongest effect was found when visual information leads the audio, +50 ms. Using fMRI the following brain areas were identified as being involved in AV integration: supramarginal gyrus, inferior parietal lobule, and superior frontal gyrus. This is still work in progress, and parts of the results are presented in this chapter. Multisensory neurons have been identified in higher centers such as superior temporal sulcus, and superior colliculus, but few studies have described multisensory integration in lower auditory centers.

Even though fMRI has come to dominate the brain mapping area since 1990’s due to its low invasiveness, lack of radiation exposure, and relatively wide availability it is a relatively expensive and time-consuming tool. Therefore, it seems unlikely that in the near future it will become a clinical routinely technique. Nevertheless, fMRI will remain one of the essential tools for brain research.